
MODELING AND SIMULATION OF LIQUID MOLDING PROCESSES

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Outline



LIMS Simulation Package Development

- ♦ **Changes and Additions**
 - ♦ Inlet Modeling
- ♦ **LIMS UI Extensions and Development**
- ♦ **LIMS Distribution Made Available**

Addressing Practical Processing Issues

Modeling Issues

- ♦ **Preform and Distribution Media Deformation**

Conclusions

The Road Ahead

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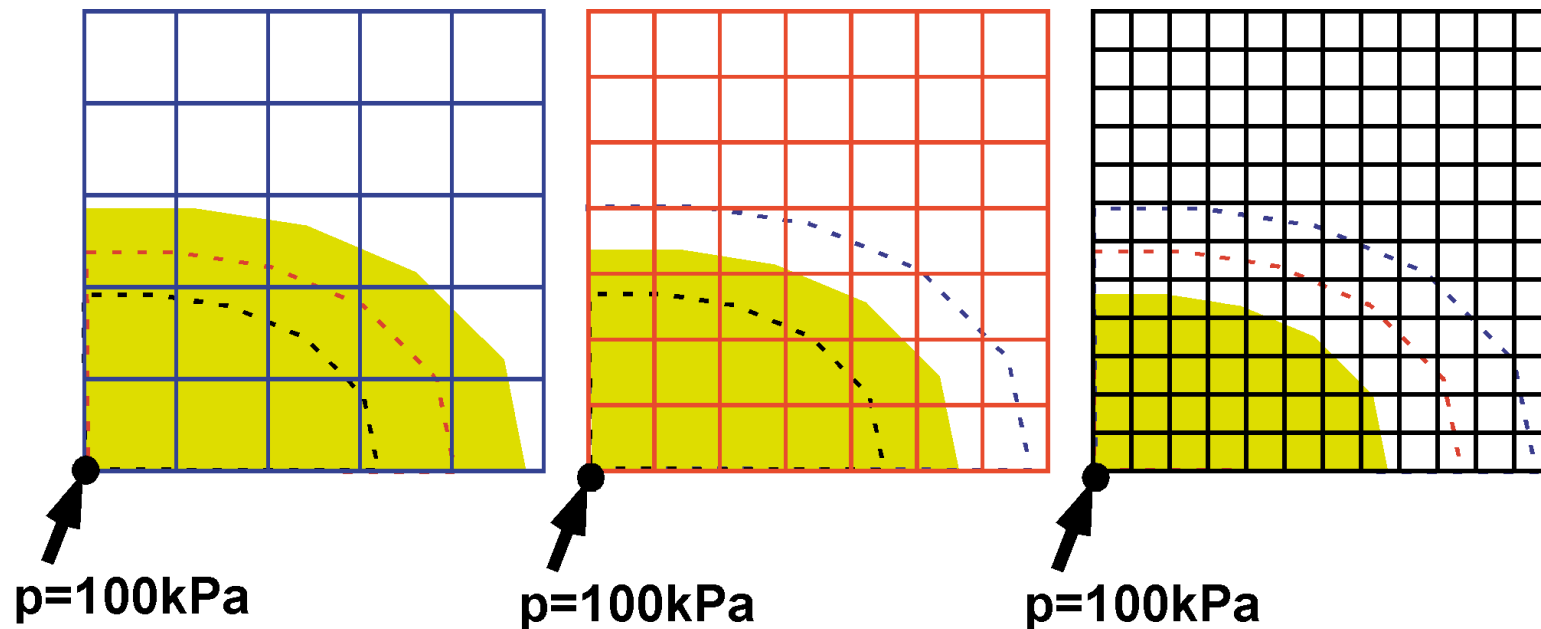
Conclusions

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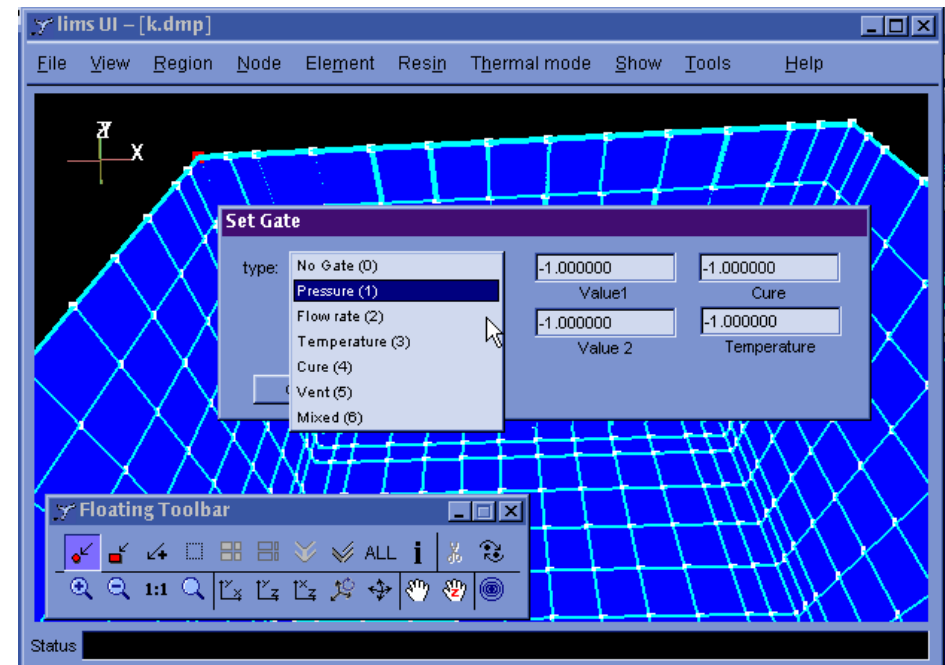
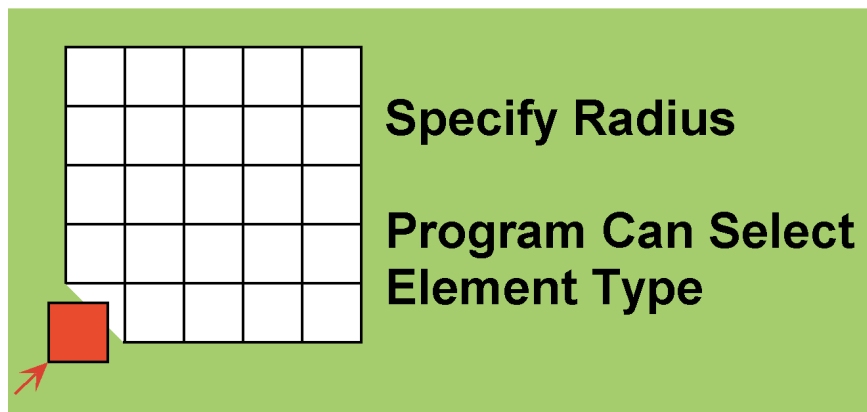
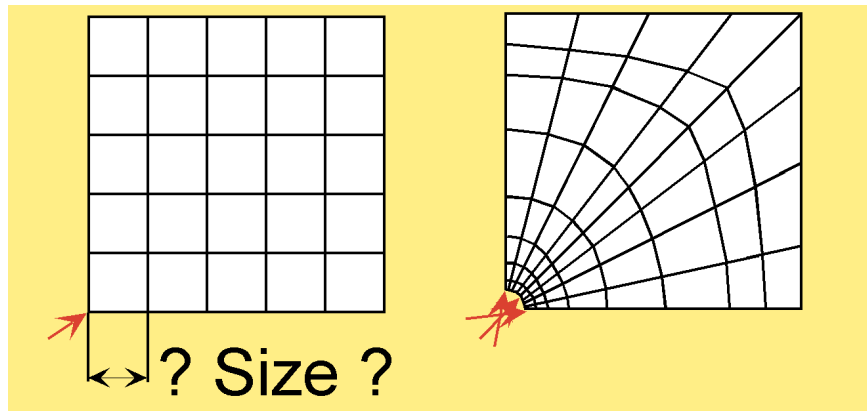
Element Size and Injection Gate



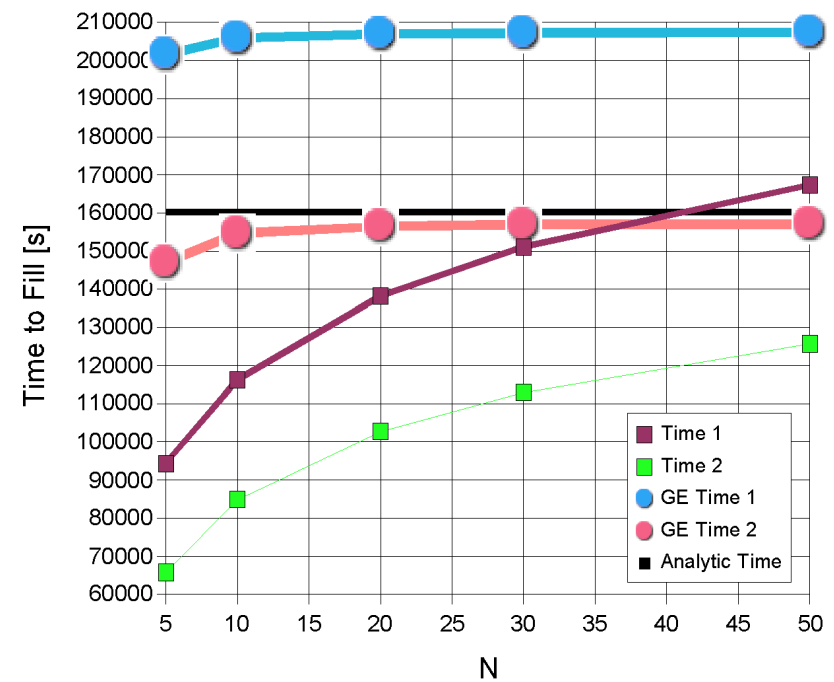
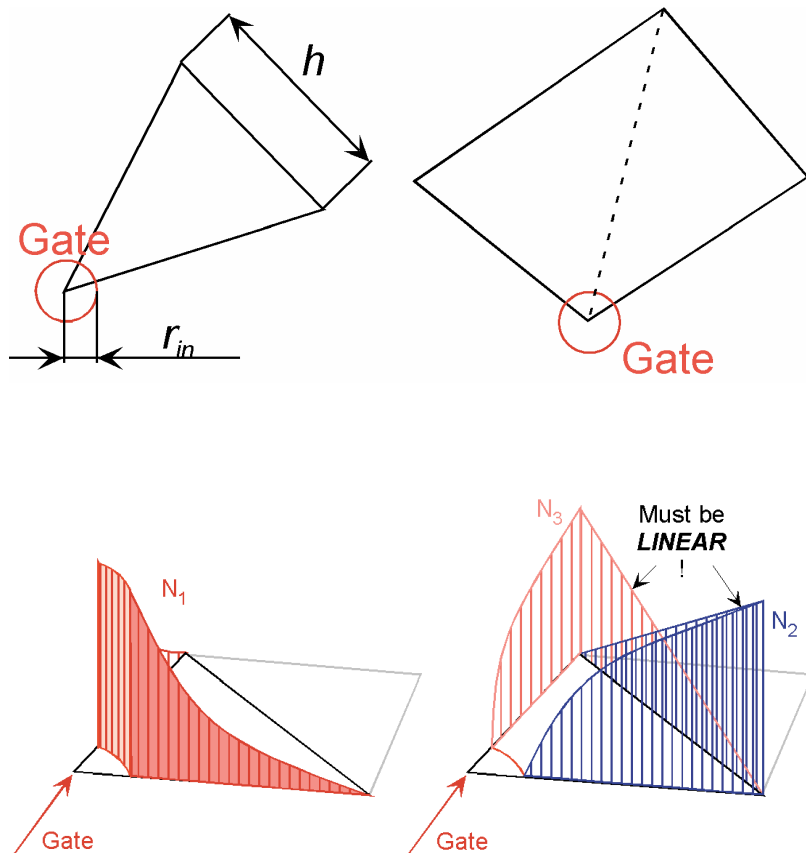
- ◆ Same Problem
- ◆ Same Time
- ◆ Refined Mesh
- ◆ Divergent Results at Given Time



“Proper” Gate Modeling and User Convenience



The “Gate Element” Implemented



LIMS UI: New Features



Injection Scheme Wizard

Toolsmenu

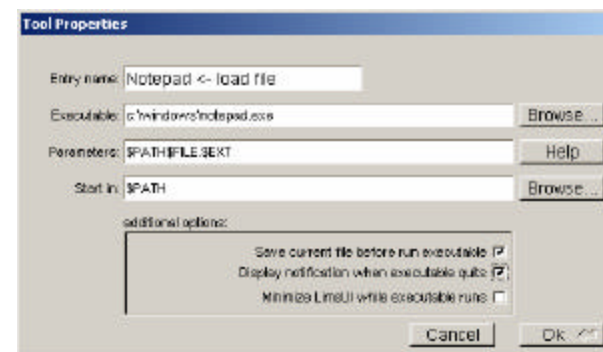
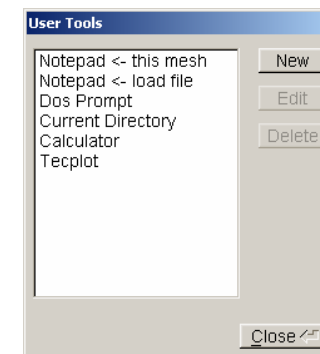
Floating Toolbar

Save (Without File Dialog)

Remove Result Section

Lots of Minor Additions and Fixes

- ♦ **Show commands passed to Lims while executing simulation**
- ♦ **Select all Gates**
- ♦ **Set Thermal Data**
- ♦ **Display Mode: 3D Elements**
- ♦ **Fullscreen Mode**
- ♦ **Select All Gates**
- ♦ ...



LIMSUI Development: Wizards



lms UI - [k.dmp]

File View Region Node Element Resin Thermal mode Show Tools Help

Standard

Injection Scheme Wizard

Step 1: Set initial gates.

Entry#	Node#	Type
00001	0000000127	initial gate

add gates/vents:

127
Node# for Gate/Vent: 02
DAQ
Pressure (1)
Type
100000
Value

Node# for Open: 01
DAQ

Injection Scheme Wizard

Step 2: Set auxiliary gates.

Entry#	Node#	Type
00001	0000000127	initial gate

add gates/vents:

139
Node# for Gate/Vent: 02
DAQ
Pressure (1)
Type
100000
Value

140
Node# for Open: 01
DAQ

Injection Scheme Wizard

Step 3: Set vents.

Entry#	Node#	Type	Open#
00001	0000000127	initial gate	

add gates/vents:

139
Node# for Gate/Vent: 01
DAQ
Pressure (1)
Type
100000
Value

140
Node# for Open: 01
DAQ

use

Cancel

telephony.bd test.lb

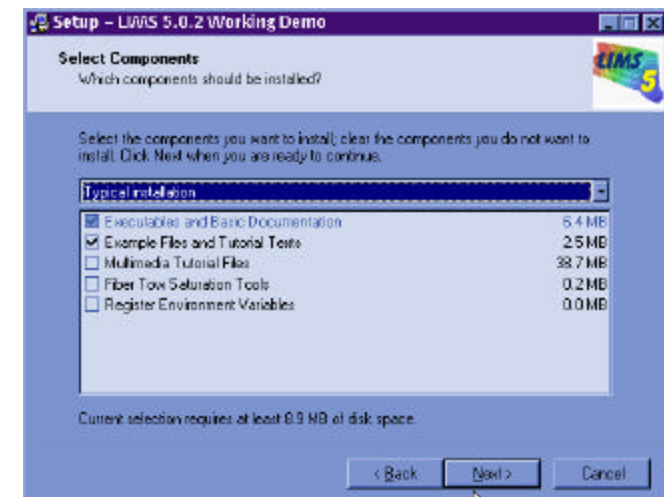
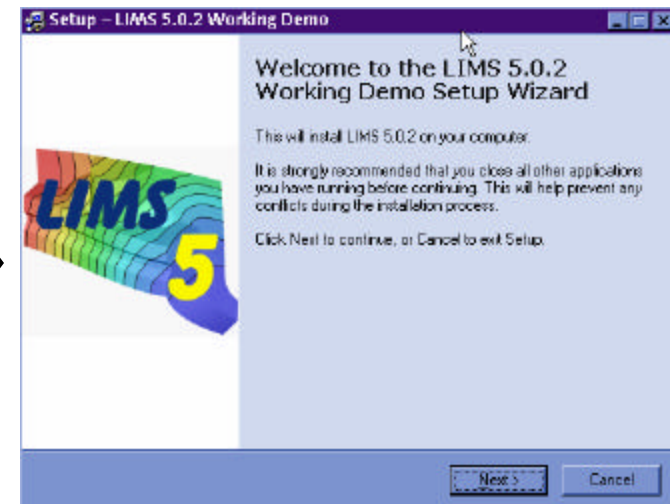
```

1 proc auto
2
3 READ "k.dmp"
4
5 setgate 127, 1, 100000
6
7 do while (sonumberempty()>0)
8 solve
9
10 if (sofillfactor(27)>0) then
11 setgate 127, 0, 0
12 endif
13
14 loop
15
16 SETOUTTYPE "TPLT"
17 WRITE "k.tec"
18
19 endproc
    
```

Status

1:1 / 19 [226] p 112 \$70 LBASIC

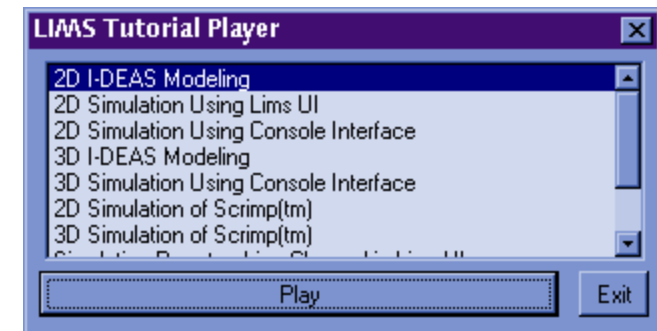
LIMS Distribution: Install CD



LIMS Distribution: Details



- **“Standard” LIMS Distribution Was Created**
 - **Setup Program**
 - **Uninstall**
- **Multimedia Tutorial Created**
 - **Supplements “Printed” Documentation**
- **“Limited” Version Distributed Without Limitations**
 - **1000 Nodes, Times Out**
- **Full Version Subject to Agreement**



LIMS Distribution: Technology Transfer



LIMS Demonstration CD

- ♦ Companies (Lockheed Martin, Raytheon Missile System, ACR, Dynasty Boats...)
- ♦ Universities

Workshops and Demonstrations

- ♦ SAMPE, JEC ...
- ♦ Workshops (ACR, 2nd July...)

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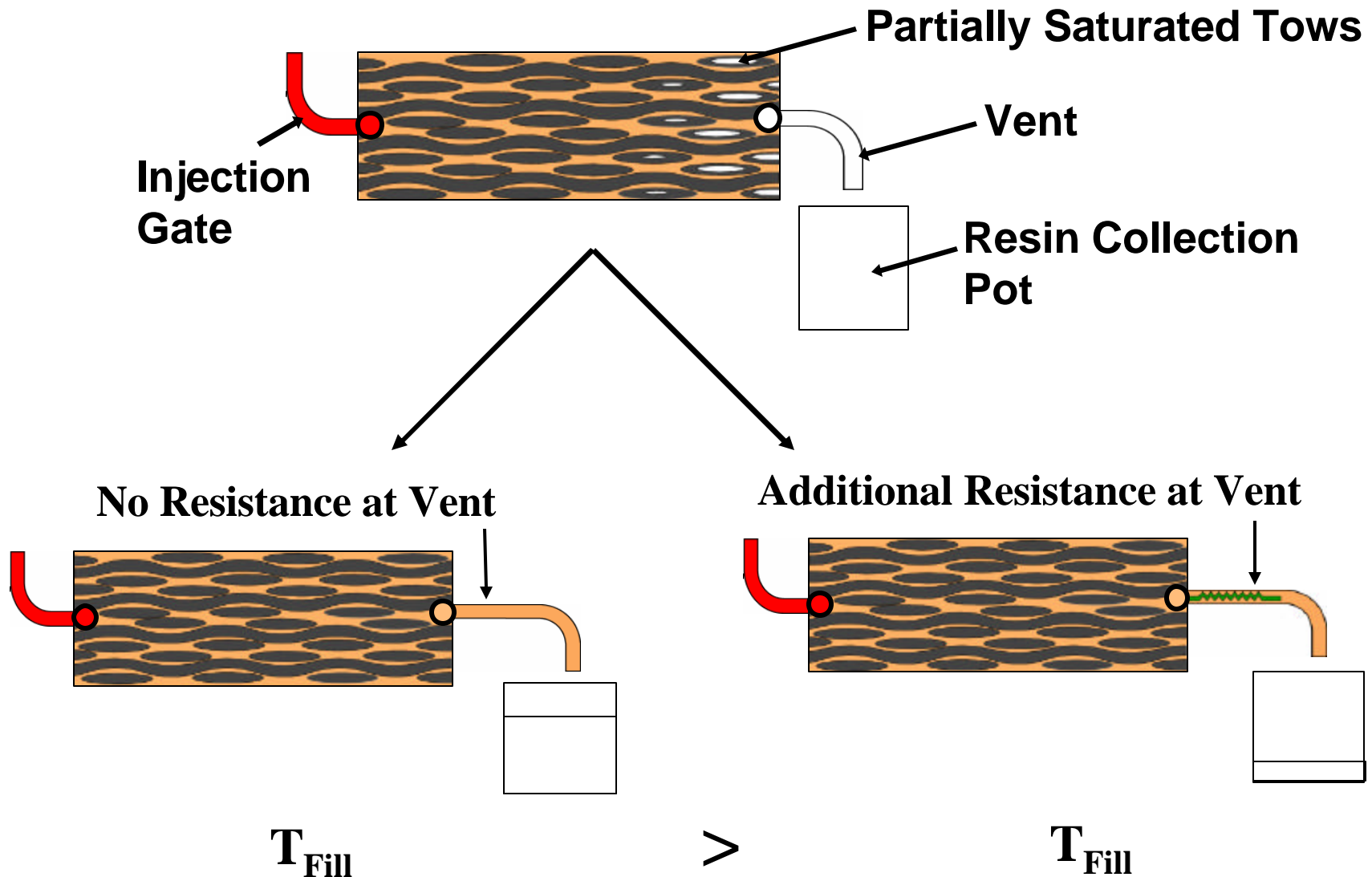
Modeling Issues

- ◆ Preform and Distribution Media Deformation

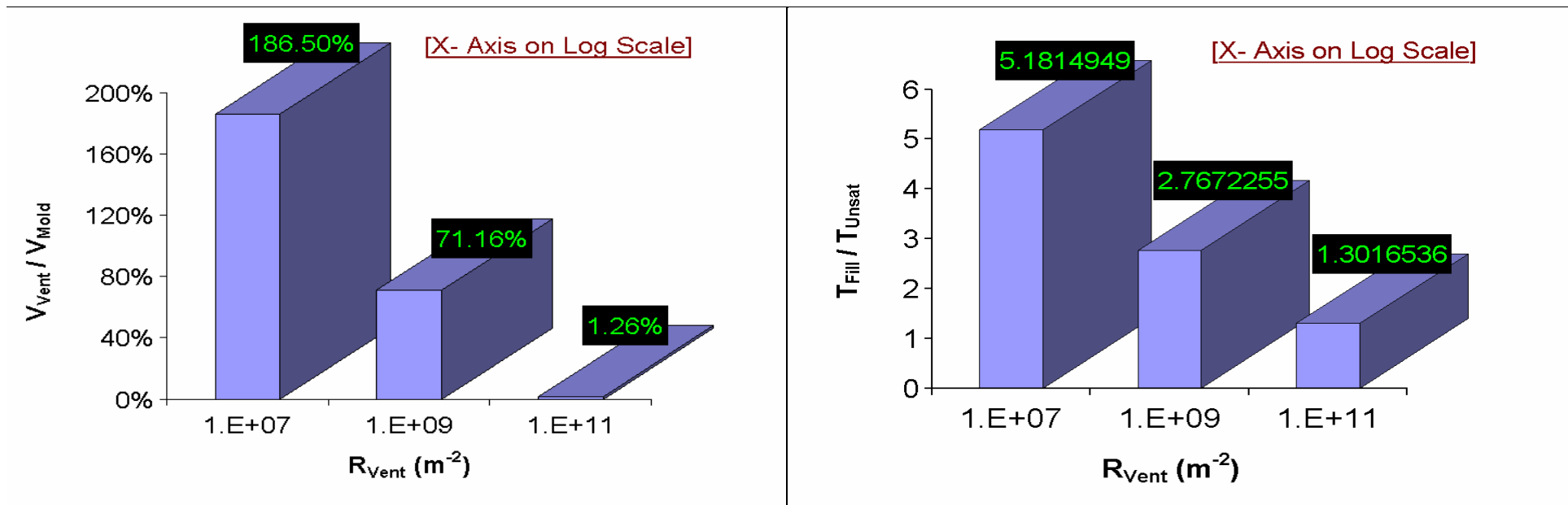
Conclusions

The Road Ahead

Modeling Flow Resistance at Vent



Effects of Flow Resistance at Vent



R_{Vent} - Resistance at the Vent

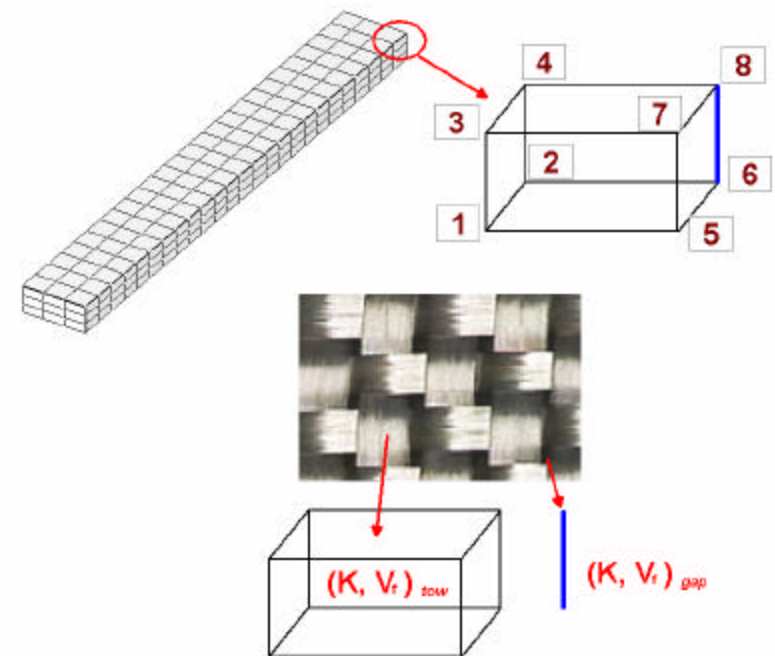
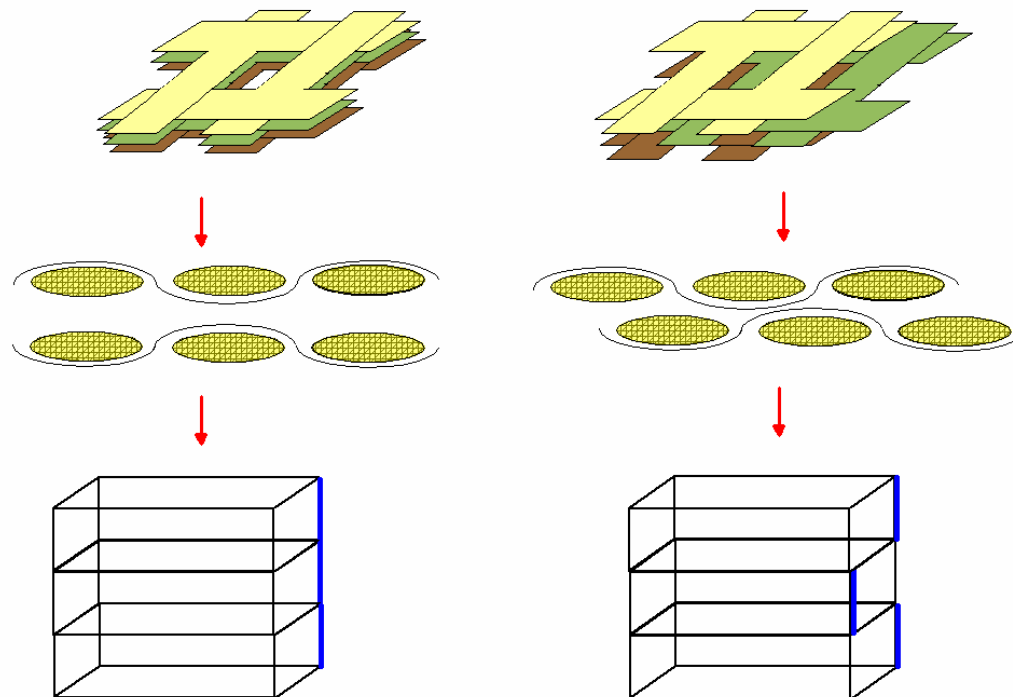
V_{Vent} - Volume of Resin Leaking out of the Vent for Full Saturation

V_{Mold} - Porous Volume of Mold

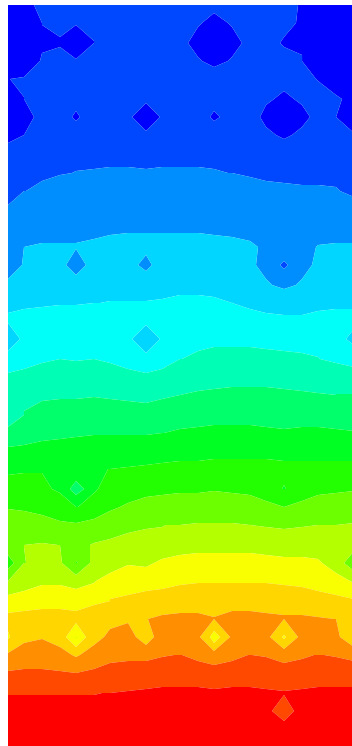
T_{Fill} - Fill-Time for Full Saturation of Mold

T_{Unsat} - Time When Resin First Reaches at the Vent

Modeling Preform Nesting Effects



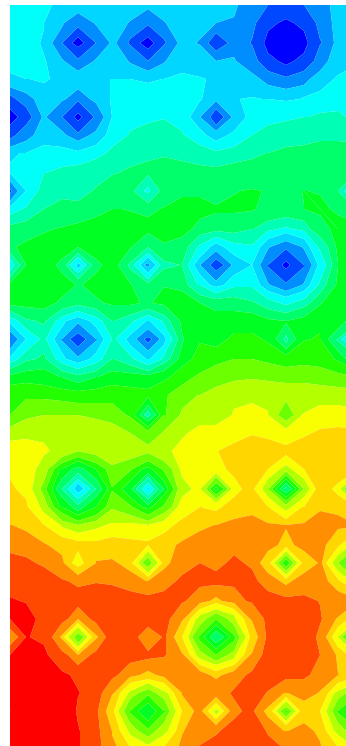
Influence of Distribution Layer Permeability



Time

237.882
222.023
206.165
190.306
174.447
158.588
142.729
126.87
111.012
95.1529
79.2941
63.4352
47.5764
31.7176
15.8588

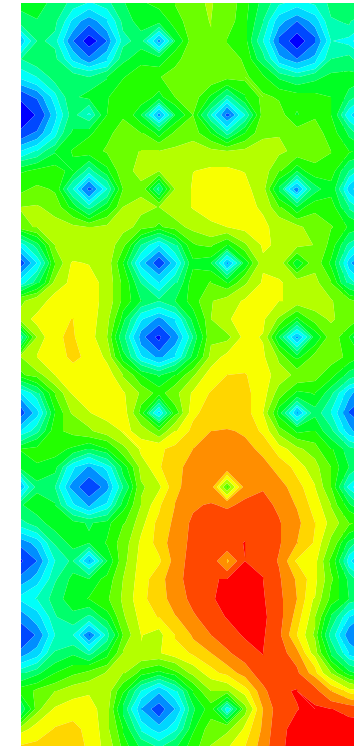
$$K_{dl} = 10^{-3} \text{ mm}^2$$



Time

44.4522
41.4887
38.5253
35.5618
32.5983
29.6348
26.6713
23.7078
20.7444
17.7809
14.8174
11.8539
8.89044
5.92696
2.96348

$$K_{dl} = 10^{-2} \text{ mm}^2$$

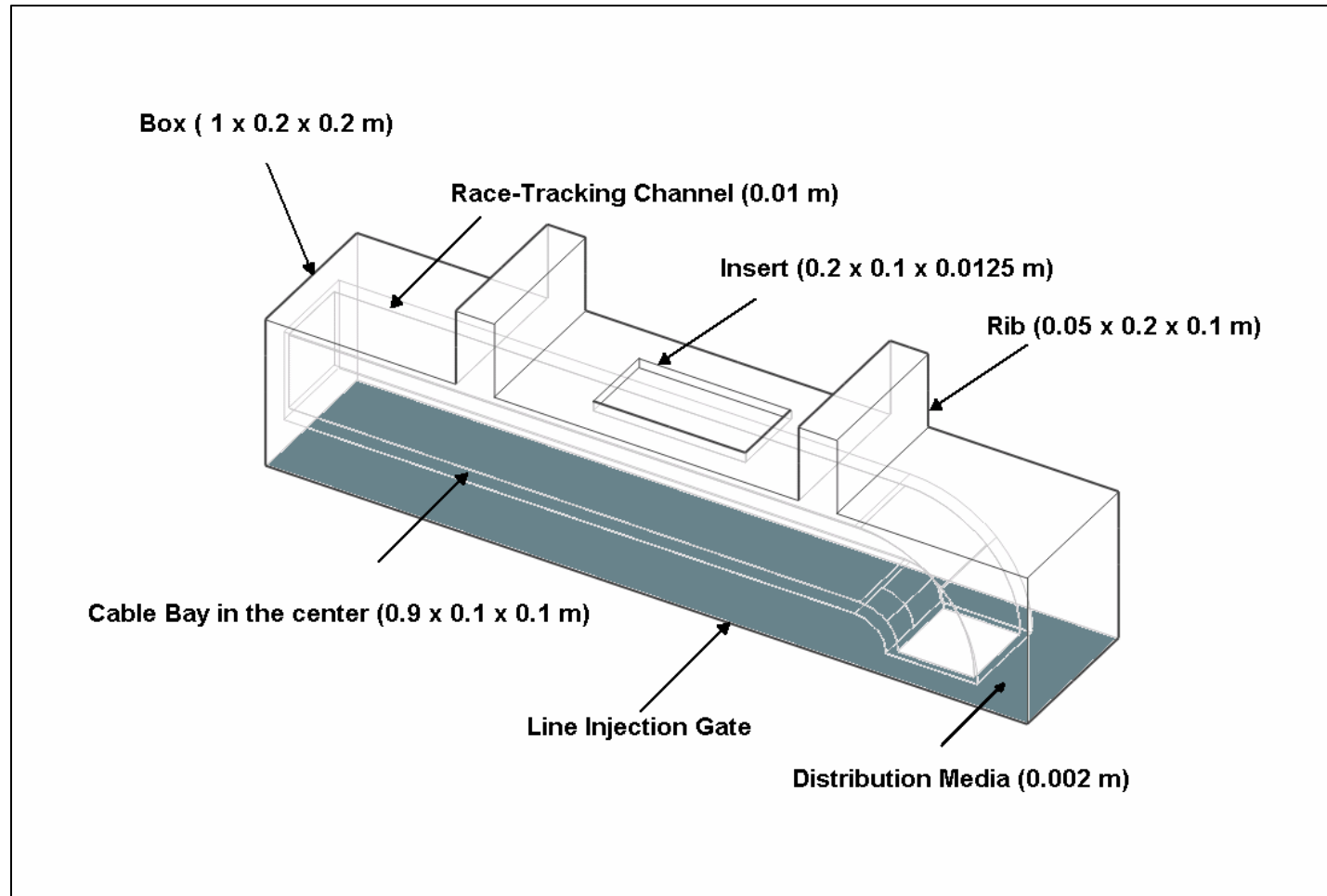


Time

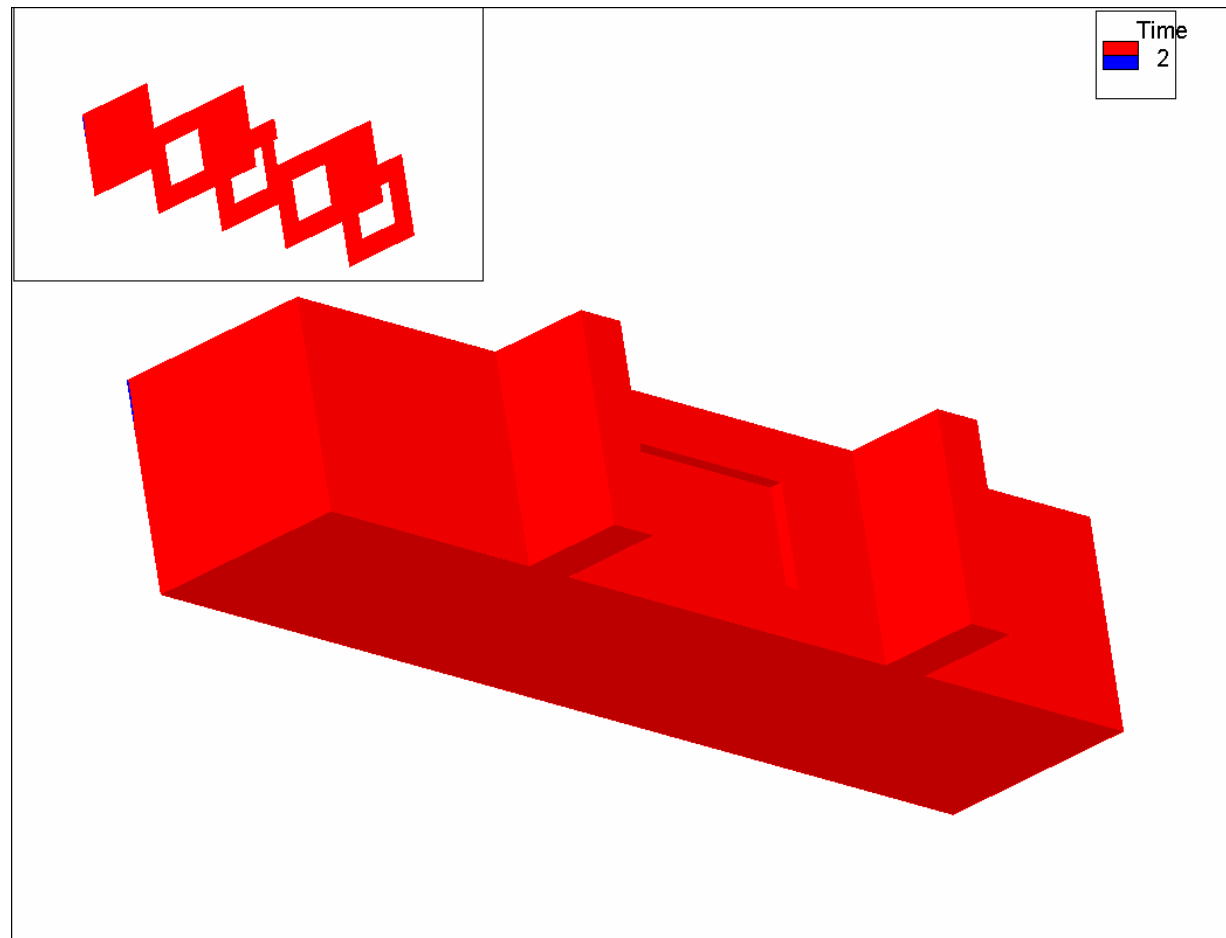
16.1802
15.1015
14.0229
12.9442
11.8655
10.7868
9.70813
8.62945
7.55077
6.47209
5.39341
4.31472
3.23604
2.15736
1.07868

$$K_{dl} = 10^{-1} \text{ mm}^2$$

Modeling Inserts and Channels Inside the Part



Integrated Part: Filling



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- ♦ **Preform and Distribution Media Deformation**

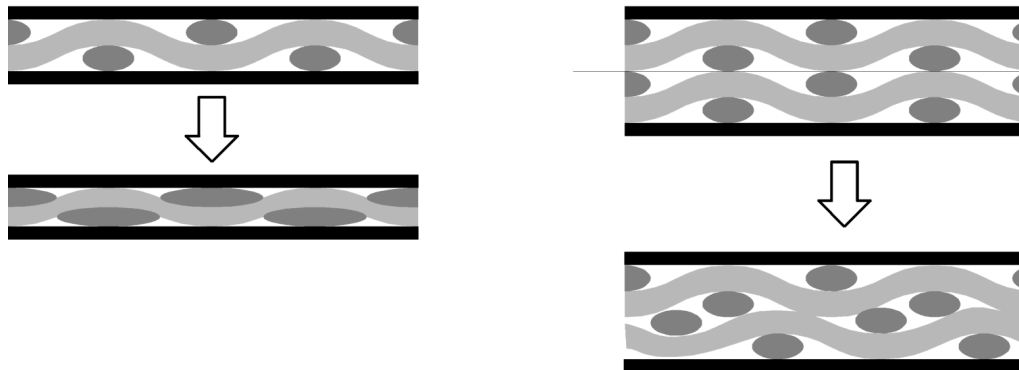
Conclusions

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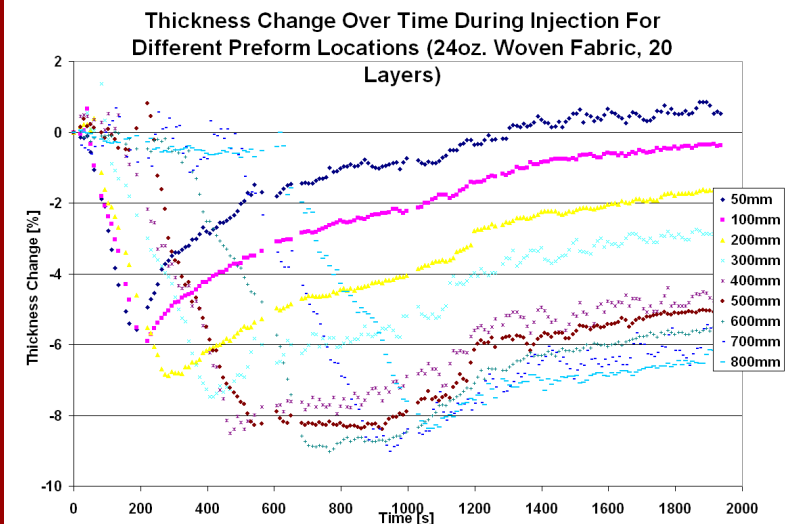
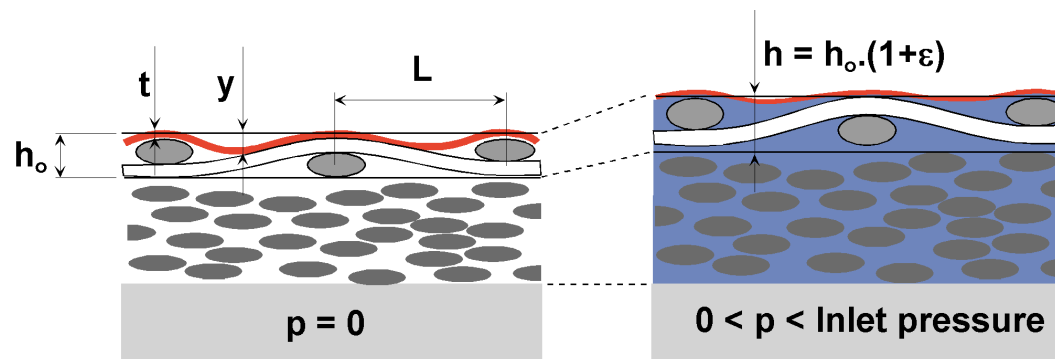
Preform & Distribution Media Deformation



RTM



VARTM

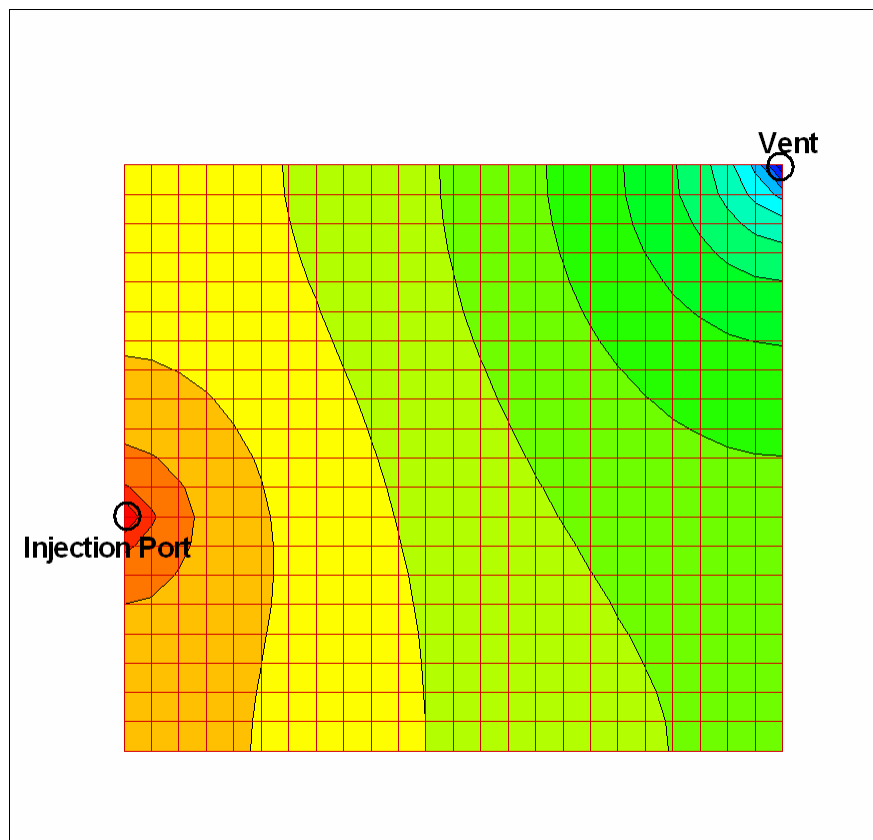


Compaction: Is It Important?

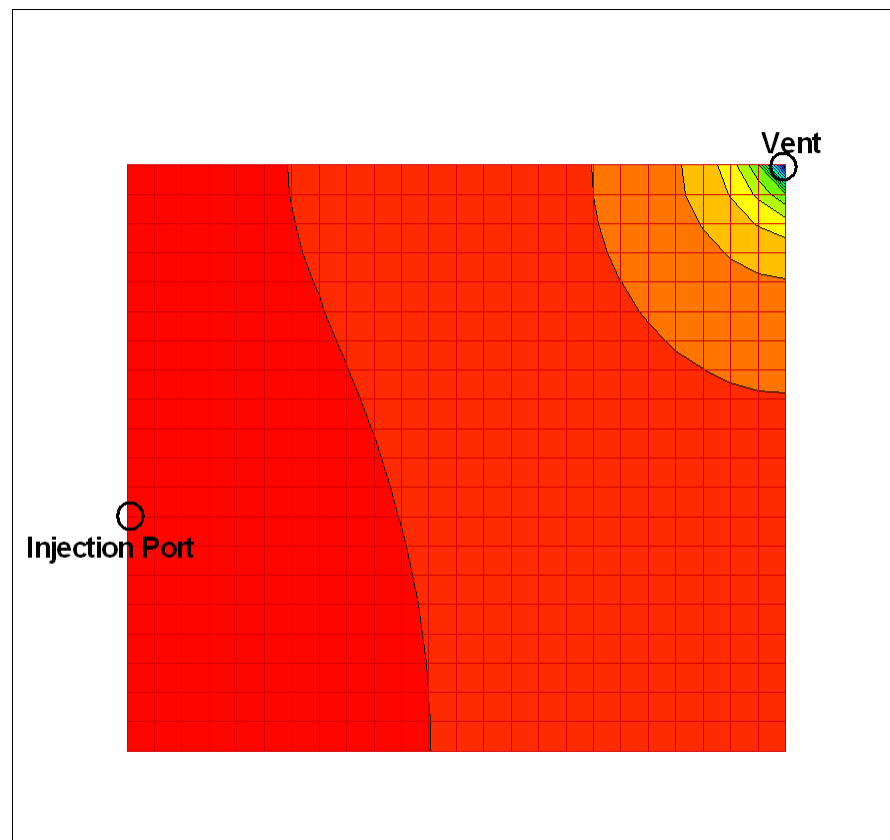


Pressure Field in Rectangular Mold (End of Injection)

No Compaction



Compaction

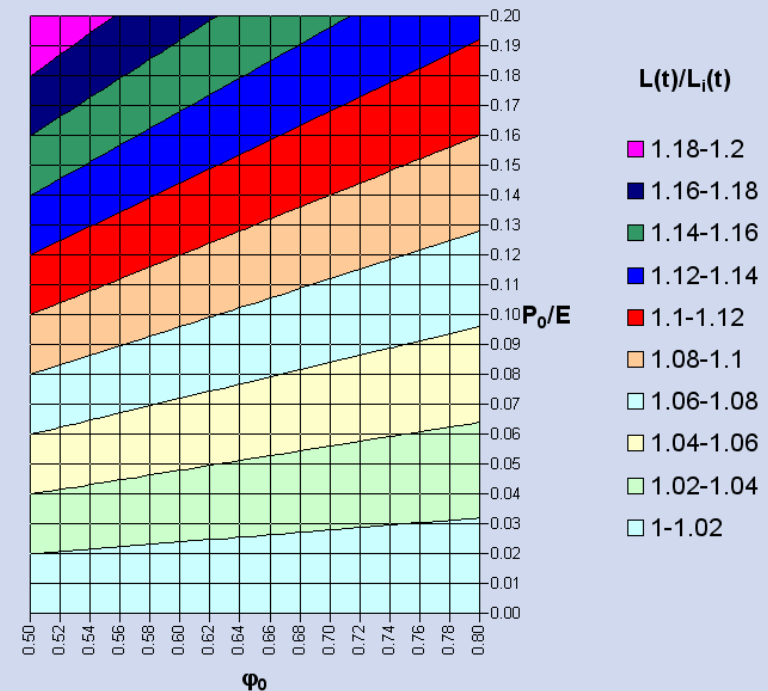


Compaction: The Analytic Solution



$$L(t) = \sqrt{\frac{10kE}{16\mu(1-\varphi_0)^2}} \frac{\left(\varphi_0 + \frac{P_0}{E}\right)^4 - (\varphi_0)^4}{\sqrt{\left(\varphi_0 + \frac{P_0}{E}\right)^5 - (\varphi_0)^5}} \sqrt{t}$$

$$\frac{L(t)}{L_i(t)} = \frac{\sqrt{5}}{4\varphi_0} \sqrt{\frac{E}{P_0}} \frac{\left(\varphi_0 + \frac{P_0}{E}\right)^4 - (\varphi_0)^4}{\sqrt{\left(\varphi_0 + \frac{P_0}{E}\right)^5 - (\varphi_0)^5}}$$



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- **Gate Elements Were Implemented and Tested**
- **Preform and Distribution Media Compaction**
 - ◆ **Influences Behavior of VARTM Process and Other**
 - ◆ **Analytic Model Was Developed**
- **LIMS UI Has Been Extended with Sequential Injection Wizard and Improved**
- **LIMS Distribution Was Completed and Made Available**

The Road Ahead



Simulation Tasks

- ♦ Numerical Solution for Deformable Media
- ♦ Re-visiting the Non-isothermal Modeling

LIMS Extension

- ♦ Extending Gate Elements into 3D Case
- ♦ Alternative (Iterative) Solver for Large/Non-Linear Problems

LIMS UI

- ♦ Connection to Databases of Material Properties
- ♦ Wizard for Optimal Filling

Credits



Students

Dhiren Modi

LIMS UI Team

Ben Lenhard

Mark Schlieker

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